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GEORGE S. RICE AND IRVING HARTMANN

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DEPARTMENT OF THE INTERIOR - BUREAU OF MINES

LIQUID CARBON DIOXIDE USED TO EXTINGUISH A GOB FIRE IN A GERMAN COAL MINE[1]

By George S. Rice[2] and Irving Hartmann[3]

A novel method of extinguishing a mine fire in a stowed or gob-filled area by employing liquid carbon dioxide under high pressure was used recently with success at the President (Prasident) coal mine, Bochum, Germany, as reported by P. Cabolet in Gluckauf (Apr. 24, 1937, p. 383).

The use of carbon dioxide gas as a fire-fighting agent in surface plants and in ships is now general practice in the United States, but when it has been tried for extinguishing fires in mines in large areas more or less confined by stoppings it has not been successful. Examples of the latter method of attempting to fight mine fires are given in Bureau of Mines Bulletin 223, Fifty-Nine Coal-Mine Fires; How They Were Fought and What They Teach, by G. S. Rice, J. W. Paul, and M. W. von Bernewitz (1927). The reason for its nonsuccess may be either that the stoppings are not tight or that the roof and pillars are more or less fissured and enough air passes into the area to sustain a slow fire, whether of spontaneous origin or produced by gas explosion or other source of ignition.

Were it possible to enclose the fire area so that no air could enter, then it would not be necessary to introduce carbon dioxide or other inert gas, as the fire itself would provide its own extinguishing gases; but there are many conditions under which it is not possible to obtain complete sealing.

The circumstances stated by Cabolet in the Gluckauf article cited are essentially as follows:

Extinguishing a Fire in a Stowed Goaf by Means of Carbon Dioxide

On November 12, 1936, a distinct burning odor and a heavy condensation of moisture on the rocks were noticed in the President coal mine in Bochum in the ninth main level, breast 3-4 east of the Dickebank seam. The seam lies in a steep fold and is irregularly formed; in the area under consideration it is in-

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2/ Chief mining engineer, U. S. Bureau of Mines.
3/ Assistant physicist, U. S. Bureau of Mines.

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clined from 80° to 90° to the horizontal and its thickness varies from 1.60 to 5 meters (5.25 to 16.4 feet).

A secondary or staple shaft, 150 meters (492 feet) deep, extending between main levels 8 and 9, is located in the vicinity of the fire area, and between sublevels 3 and 4 this shaft has concrete walls for reinforcement (see fig. 1). The sublevels of the several working breasts are 25 meters (82 feet) apart as measured on the pitch. As a result of acute folding, the coal is soft and friable and liable to run out from the breast where undercut, so that the inclined breasts, approximately 50 meters (164 feet) in length along the incline, must always be supported by planks and timbers. Mining in this part of the mine was suspended temporarily at the beginning of August 1936.

The mining excavations were backfilled with slack obtained from two adjacent mines. The slack contained 30 to 45 percent coal, which had a sulphur content of 3 to 5 percent.

As previously stated, on November 12, 1936, a fire was discovered in the mine. An examination indicated that the stowing material had been ignited spontaneously in the area below the inclined breast at a point midway between 3 and 4 east sublevels. After shoveling off the surface of the heated gob, temperatures of 60° to 85° C. (140° to 185° F.) were measured at a depth of only 0.30 meter (12 inches) in the backfilling, and dense water-vapor clouds arose from the gob. However, no flame could be observed. An analysis of gases from the burning area showed 0.003 to 0.009 percent CO, 1 to 1.5 percent CO_2, and 0.30 to 0.35 percent CH_4.

The first step was to try to seal the fire by covering over the gob by a 2-meter (6.3-feet) thick layer of fine-grained sand, extending from the concrete wall of the staple shaft along sublevel 4 and down the inclined surface of the goaf area to sublevel 3 (see fig. 1). Then, midway of the incline, several channels were cut in the sand seal, and water was supplied to these through a flexible hose. After some time the flow of water was stopped, whereupon heating of the gob again took place and the fire revived. The intensity of the fire, however, had been lessened and its location had shifted down toward sublevel 3, as air probably was still getting to the fire by seeping through the gob from this sublevel.

An attempt to obtain air-tight sealing over sublevel 3 by the method of cementation seemed useless because of the fissured nature of the surrounding rocks and consequent movement from ground pressure on the sublevel. Likewise, a general removal of the gob material on fire was not considered feasible because of

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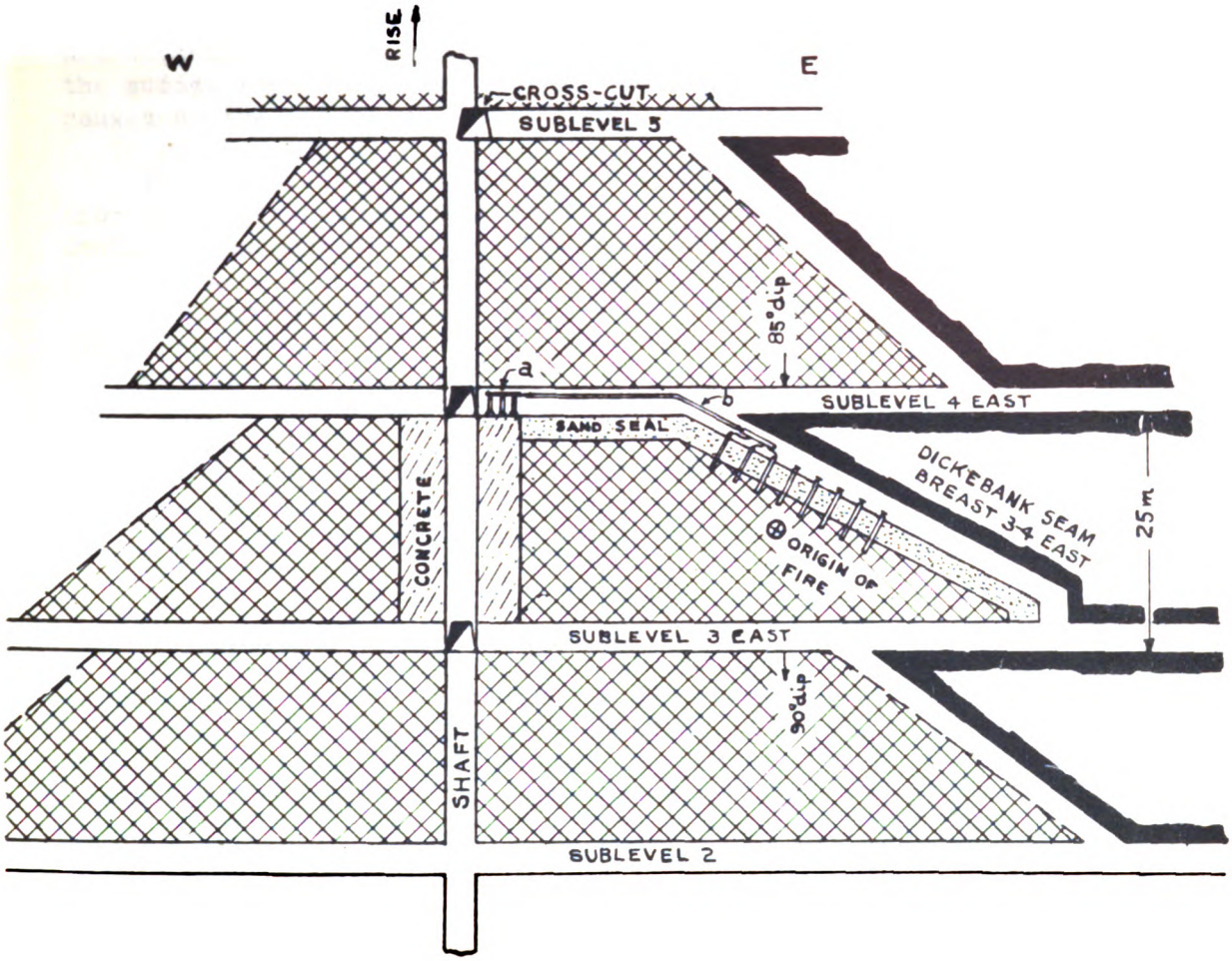

LEGEND: a: LIQUID CO_2 CYLINDERS AND COLLECTOR PIPE
b: HIGH PRESSURE DISCHARGE PIPE

Figure 1.—Elevation of workings in the vicinity of gob-fire, President coal mine, Bochum.

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the irregular, very weak nature of the hanging wall and foot wall of the seam; also, it was probable that the timber had been charred and weakened by fire in the gob area and that there was danger of the sudden running out of the overhanging coal face, which might be caused by the effect of occasionally occurring bumps.

In an inspection on November 20, 1936, a burning odor and unusual heating suggested a continuation of the fire. It was then decided to combat the fire by introducing carbon dioxide under pressure into the gob. Sixteen pipes each 3.5 meters (11.5 feet) long, arranged in two parallel rows 2 meters (6.6 feet) apart, were inserted through the sand cover and part way into the gob near the probable seat of the fire (see fig. 1). At their inner end, for a length of 0.5 meter (1.6 feet), each pipe was perforated by 16 to 20 drillholes of 4 to 6 mm (0.16 to 0.24 inches) diameter. The liquid carbon dioxide was to be supplied to these pipes at a pressure of 70 atmospheres (1,030 pounds per square inch), according to the process of the firm Walther & Co. of Koln-Delbruck.

On the night of Saturday, November 28, 1936, 25 carbon dioxide cylinders, each of 30 kg (66 pounds) capacity, were placed in sublevel 4. These cylinders were of special steel construction and had been officially tested at a pressure of 190 atmospheres (2,790 pounds per square inch). They weighed 100 kg (220 pounds) and were equipped with quick-opening valves of large discharge area to permit rapid discharge of large quantities of carbon dioxide. On the morning of November 29, 1936, the liquid carbon dioxide was injected into the gob. From the cylinders the carbon dioxide passed as a liquid through submerged tubes into the collecting pipe "a", provided with a check valve and manometer, and then was led through the high-pressure tube "b" of 50-meter (164 feet) length to the pipes inserted in the gob, reaching the fire area in gaseous form (see fig. 1).

To protect the men engaged in this work, a rescue crew equipped with four breathing apparatus went along. The discharge of the 750 kg (1,635 pound) of liquid carbon dioxide of -57° C. (-70.6° F.) temperature took place without interruption in about 2 hours. There was no indication of any escape of carbon dioxide from the gob into the two roadways or through the covering layer of sand; apparently, therefore, it was distributed uniformly through the gob around the discharge ends of the pipes.

Four hours after the introduction of the carbon dioxide no further heating effect of the gob could be noted. An inspection of the area some 12 hours after the injection disclosed no outflow of carbon dioxide gas at any place around the breast. The burning odor in the breast and in the return airway of the breast likewise had vanished entirely.

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To make certain that the fire was out, on December 12, or 14 days after the introduction of the carbon dioxide, a gas sample was taken from the return of this breast; analysis of this sample by the official mining laboratory gave 0.12 percent CO_2, 0.12 percent CH_4, 0.00 percent CO, 20.52 percent O_2, and 79.24 percent N_2. As no CO was found and as the CO_2 and CH_4 contents corresponded to the normal atmosphere of the Dickebank mine workings, it was considered practically certain that the carbon dioxide injection completely extinguished the fire. After three more months, upon resumption of work in the eight working breasts of this division, there was still no evidence of its recurrence. The quick subduing of the fire by the introduction of carbon dioxide under high pressure and low temperature thus made unnecessary the complete sealing up and abandonment of a developed mine area of daily producing capacity of 500 tons of coal.

CONCLUSIONS DRAWN BY THE AUTHORS

The success attained in the extinguishment of a gob fire in a German mine by injection of liquid carbon dioxide into the burning mass suggests trial of this method on gob fires occurring under similar conditions in mines of the United States where direct means of extinguishing, as by the employment of rock dust followed by water or the use of water alone, have failed.

As indicated in the German report quoted above, for the method to be effective, the fire area must be enclosed as tightly as possible by seals or sand covering to keep the carbon dioxide concentrated and to exclude oxygen from the fire so that not over a few percent is present.

It has been shown by attempts made in the United States that simply spraying carbon dioxide gas onto a gob fire in imperfectly sealed abandoned workings has little merit.

Admittedly, the cost of the liquid carbon dioxide method applied in the German mine is costly, but the use, as in that case, is justified when it permits recovery of a part of the mine and removes the danger always present in a mine where there is an active or smoldering fire even if the area is more or less confined by stoppings.

Several physical factors may be involved in the successful use of the method:

A. The rapid application of high concentrations of carbon dioxide in the liquid phase into the fire area keeps fresh air from reaching the site of the fire by the action of the initial mechanical discharge pressure and

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subsequently by the local pressure developed during the expansion of the gas, which will make a blanket of inert gas surrounding the seat of the fire.

B. The local concentrated cooling effect of the very low temperature liquid carbon dioxide, in addition to the absorption of heat in the vaporizing of the liquid reduces the temperature of the burning particles to a degree such that, combined with the effect of restricted oxidation through the presence of the inert gas, combustion is likely to cease.

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